which trinket he will select for his mental adornment.

Perhaps all of us can get together again on common ground by putting our concepts of nature-action into simpler, more comprehensive formulas, universal in application, and somewhat as follows. In so far as we have a right to assume that purposeful action is involved in any constructive functioning whatever, or in anything that has been accomplished, we may assume that the purpose, or grand strategy in nature-action, is evolution, or self-construction, or growth. To that end, serviceable agents must first exist, or be constructed, in which is resident a basic right to receive service, and a basic obligation to give service. As all constructive action is contingent on the fulfilment of these mutual rights and obligations, the categorical imperative to existence is mutual service.

As corollaries to this categorical imperative, the following compulsions are laid upon these constructive agents. In all sustained constructive action there must be: (1) A mutual directive discipline, or mutual adaptation; that is, a mutual subjection, and yielding to one another's influence. (2) An individual freedom of opportunity for self-constructive, or egoistic action, within rigidly circumscribed limitations. (3) Mutual service or cooperative action, in which, soner or later, the profits of egoism must be surrendered, through altruism, to some ulterior creative act. (4) Conservation of these profits as an accumulating capital in constructive rightness, and its endowment to other individualities for usage in further constructive action.

In that phase of cosmic evolution which we call social growth, science and religion are the outstanding cooperative agents. They better serve their ulterior purposes the better their mutual services, and the better their mutual adaptation of thought and act to creative ends.

Science and religion always have asked, and doubtless always will ask, the same fundamental questions. What creates, what preserves, and what destroys the products of nature, and how may man profit thereby? The answers, whatever they may be, must ultimately be expressed by them in essentially equivalent terms, their verification sought in constructive action.

The large element of unpredictable returns resident in all phases of nature-action demands trial; creative turns justify the experiment.

These unsuspected potentialities are revealed in the triumphs of nature's creative art and thus confirm her independence of established laws and precedents. Therein is the source of man's undying hope and faith, his abiding impulse to endeavor.

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ON NIPHER'S "GRAVITATIONAL" EXPERIMENT AND THE ANOMALIES OF THE MOON'S MOTION[1]

From his assumption that matter is entirely electrical, Fessenden concluded[2] that the atoms in the interior of solid bodies are charged electrically, contrary to a common conception that a static charge resides wholly on the surface. Fessenden's assumption has now been completely confirmed by Professor Francis E. Nipher's experiment with an electrified Cavendish apparatus,[3] which shows that when thin electrified shells of metal are substituted for the large leaden spheres, no effect is produced on the inner small suspended spheres, protected by a metal case, when the electricity is applied. This, of course, simply corroborates Faraday's "ice-pail" experiment. But when the large leaden spheres are restored to place and electrified, the electricity gradually soaks in, and after about half an hour this interior charge of the atoms has accumulated sufficiently to produce an electrical repulsion of the small spheres, greater than their original gravitational at-

[1] This paper was read at the twenty-second meeting of the American Astronomical Society at Harvard College Observatory, August, 1918.

[2] *Electr. Soc.*, Newark, 1890; *Electr. World*, August 8–22, 1891.

[3] "Gravitational Repulsion," *Transactions of the Academy of Science of St. Louis*, Vol. XXIII., p. 177, 1917.

traction by the material of the unelectrified large spheres. Professor Nipher calls this a "gravitational repulsion," but this appears to be a misnomer. If the lead had really become *gravitationally* repulsive, it should also repel the earth, and the leaden spheres should rise up and float away. Needless to say, this is not what happens. Contrary to the usual conception of a static charge, *the electric charges have penetrated into the substance of the metal.* Since it is thus shown that a charge of electricity, which in other respects would not be distinguished from a static charge, has in this instance slowly been absorbed by the metal, permeating its substance, the thin metal of the protecting case can be no barrier to the transmission of such a charge as this, and the metal case no longer protects the inner balls of lead from directly receiving a corresponding electric charge of the same sign as that of the large spheres, and thus there is repulsion between the two, no matter whether the electrification be positive or negative. However, since the electric penetration progresses very slowly, the large spheres presumably take more time to charge up than the small spheres. Consequently, if after a preliminary application of one sort of electricity for a sufficient time to produce saturation, the electrification is changed to the opposite sort, we should expect that the electrification of the small spheres would change sign first, and for a while there should be electric attraction, or at least a progressively diminishing repulsion. Now this is exactly what takes place, though sometimes with rather vigorous tremors, as if the interior distribution of the electricity were not quite uniform and as though its unloading were spasmodic; but eventually, if the experiment endures long enough and the electrification is sufficiently powerful the signs of the electric charges become the same in both large and small spheres and the temporary electric attraction changes back to a repulsion. There are some anomalies connected with the orientation of the applied electricity when direct contact of brushes is the method of application, which possibly signify that the lead spheres are not entirely homogeneous for charges communicated in this way.

While the gravitational and electrical forces are intimately related, insomuch that a common entity—the electron—is presumably concerned in both, their modes of action and speeds of transmission appear to be entirely different. The electric phenomena which counterfeit gravitation in the preceding experiment, are irregularly variable and slow. Gravity is constant and its impulses so rapid in their transmission that their speed has never been directly measured. There is no reason to suppose that gravity is conveyed by electro magnetic vibrations with the speed of light, for these uniformly give repulsion, and not attraction; nor is the final action of the penetration of the electric charges other than repulsion, while, in spite of Professor Nipher's title, there is no evidence of any *gravitational repulsion.*

From the result of Nipher's experiment, we may infer that the penetration of electrons, emitted by the sun from time to time and entering into the substance of earth and moon, will produce a variable electric repulsion between these neighboring bodies, and it is conceivable that some of the unaccounted irregularities in the moon's motion may be produced in this way.

The positive electric potential of the atmosphere increases in an upward direction, at first slowly, then more rapidly, though sometimes quite irregularly, often attaining a value of tens of thousands of volts at a height of a few miles. This electrification of the air is the result of the ionization of some of its ingredients through absorption of the sun's rays. The ionization is greatest in the upper air, partly because the incoming rays are there rich in the ultra-violet rays which are the most efficient ionizers, and the upper layers are the ones which first take toll of the radiation before these rays have been depleted; but the electrification is also greater in the upper air partly because these layers are furthest from the surface of the ground and can not lose their charge by conduction to the ground as easily as the lower layers. Although air is a very imperfect conductor,

the section of this conductor being equal to the entire surface of the globe is enormous, compared with the distance to be bridged; and thus the minute specific conductivity of the air multiplied by the section and divided by the length of the path is still an appreciable quantity even locally, and a very large one taking the earth as a whole. Moist air conducts better than dry, and the electrification at a given altitude is on the average several times as great in winter as in summer, because the drier air of winter is a better insulator.

The following examples are from U. S. Weather Bureau observations at Drexel, Nebraska, in 1917 (e = mean pressure of aqueous vapor in the air up to the given height, measured in millibars; v = positive electric potential of the upper layer in volts).

Height Above Sea-level, Meters	Jan. 11, P. M.		Jan. 18, A. M.		Jan. 26, A. M.		June 12, A. M.		June 19, A. M.		June 23, A. M.	
	e	v	e	v	e	v	e	v	e	v	e	v
500	1.44	410	2.39	390	2.17	1,130	12.48	0	10.06	0	18.47	0
1,000	1.43	3,420	2.04	2,090	2.14	7,520	10.18	0	8.97	40	15.24	0
1,500	1.62	6,355	1.89	6,160	2.62	17,735	10.46	0	8.40	320	13.27	0
2,000	1.80	9,645	1.67	7,625	2.76	20,775	7.73	315	7.86	870	10.65	310
2,500	1.87	14,650	1.35	12.280	2.79	22,300	7.00	805	7.21	1,245	9.56	490
3,000	1.91	19,850	1.13	16,085	2.71	25,060	6.75	1,295	6.68	1,710	8.74	340
3,500					2.57	26,835	6.46	1,785	6.07	2,405	7.82	480
4,000							6.40	2,270	5.50	3,255	7.24	535
4,500									5.10	4,200	6.70	550

On the given dates in January, which are fairly typical, the average positive electric potential was 20,332 volts at 3,000 meters for $e = 1.92$ m.b., and in June a potential of 1,375 volts was found at the same height for $e = 7.39$ m.b. So far as ionization of water vapor is concerned, there should be more of it in June per unit volume of air; but in spite of this, the greater atmospheric conductivity at that time cuts down the potential to a much lower value than the winter one. Evidently there is continual conduction from the air to the ground. This does not neutralize the negative charge of the ground, partly because of the large electric capacity of the latter, but mainly because the prevalent negative charge of the earth as a whole is continually being restored. Except for convective uplifting of local bodies of air temporarily negatively charged by contact with the ground, these conditions of electric distribution in the atmosphere are fairly persistent. The two electricities are continually combining, but are as constantly replenished.

The incoming electrons from the sun may be absorbed by the upper air, but they serve to increase the absolute potential of the earth by a process which is independent of the radiant ionization; and as I have shown that there is conduction between the upper and lower layers of the atmosphere and adjustment of its ever varying charges, the increased absolute potential of the upper air is eventually, and probably pretty rapidly, transferred to the ground. Thus the ground receives its permanent negative charge from the sun; and in spite of all sorts of irregular electric variations in the intervening atmosphere, the permanent negative charge of the ground is maintained with only such minor fluctuations as occur in magnetic storms. In these, the showers of electrons received by the earth from the sun at times of great solar activity certainly penetrate into the earth's solid substance almost immediately, in spite of atmospheric obstruction, and produce electric "earth currents" of considerable magnitude. We must conclude that the absolute potential of the earth is continually varying.

Newcomb's investigations of the inequalities of the moon's motion[4] indicate the existence of unexplained fluctuations in the moon's mean motion—a great fluctuation possibly with a period of between 250 and 300 years,

[4] Monthly Notices of the Royal Astronomical Society, Vol. LXIX., p. 164, January, 1909.

though the change may prove aperiodic, and a lesser one of about 70 years. Professor Newcomb says:[5]

> Taken in connection with the recent exhaustive researches of Brown, which seem to be complete in determining with precision the action of every known mass of matter upon the moon, the present study seems to prove beyond serious doubt the actuality of the large unexplained fluctuations in the moon's mean motion to which I have called attention at various times during the past forty years.

And he concludes, after examining every known cause of motion, that "if we pass to unknown causes and inquire what is the simplest sort of action that would explain all the phenomena, the answer would be—a fluctuation in the attraction between the earth and the moon."[6] This is in line with my present suggestion, but as yet we have no certain knowledge whether there is correspondence between the supposed attractive change and the solar emission of electrons. However, the comparison which Professor E. W. Brown has made between the variation of the moon's mean motion in longitude and the fluctuation in height of the maxima of the sun-spot curve[7] lend considerable confirmation to the view that the 70-year period in the moon's motion is in fact due to a varying electric repulsion between the moon and the earth owing to the larger reception, by both bodies, of negative electrons when sun-spot maxima are highest and when, presumably, solar electronic emission is exceptionally great, with consequent slight reduction of gravitational control and loss of motion owing to electronic repulsion. We might suppose that the electrons thus received by our earth from the sun, form a fluctuating electronic "atmosphere," outside of the denser air, but attached to the planet. Nipher's experiment, however, favors the supposition that there is actual electronic penetration into the solid substance of the outer layers of the earth.

[5] *Op. cit.*, p. 164.

[6] *Op. cit.*, p. 169.

[7] See Report of the Australian meeting of the British Association for the Advancement of Science, *Transactions Sect. A*, pages 311 to 321.

Professor Brown says:[8] "With some change of phase the periods of high and low maxima correspond nearly with the fluctuations above," referring to his curve of the variations of the moon's motion in longitude, where negative values of the moon's motion-variation from the mean follow close after the high sun-spot maxima of 1780 and 1850, while positive lunar values (that is, increased speed from greater total attraction) are equally associated with the low solar maxima of the epochs near 1815 and 1885, or half way between the epochs of high sun-spot maxima. Nevertheless, as the electric hypothesis was then unbroached, Brown considered the connection open to doubt because, as he says, "it is difficult to understand how, under the electron theory of magnetic storms, the motions of moon and planets can be sensibly affected." But this difficulty which was felt when the only hypothesis in sight was that of some sort of *magnetic* effect, disappears in the light of the now known efficacy of electronic penetration. Similar, though much smaller variations, with apparently identical period, are found in the motions of Mercury and the Earth in respect to the sun, but in these there are some discrepancies, and until these are cleared up, the proposed explanation, though plausible and perhaps even probable, can not be considered as certainly established.

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PROFESSOR WHITMAN was of New England stock. The Whitman (originally Wightman) family came to Massachusetts in 1632. The line of Whitmans has included three clergymen. The father of Frank was William Warren, early in life a lawyer, but later engaged in business, who died in 1902, at the age of eighty-two. Caroline Keith Perkins, the mother of Frank, died at the age of forty-one. She and the mother of President Taylor,

[8] *Op. cit.*, p. 321.

[1] Minute adopted by the Undergraduate Colleges of Western Reserve University.